curriculum followed is also given, and it will be of interest to both engineers and others to note that the course at Karlsruhe includes political economy and labour problems. There is also a greater tendency in Germany for the various branches of engineering to be treated by professors who are also engaged in practical work. On another point the institution at Karlsruhe differs from the colleges in this country, namely, the students themselves. There appear to be no student organisations, and the sociability so characteristic of an English college is almost entirely wanting.

SOCIETIES AND ACADEMIES.

LONDON.

Royal Society, June 27.—"The Annealing of Copper, with Special Reference to Dilatation." By Prof. T. **Turner** and D. M. **Levy**. Communicated by Prof. J. H. Poynting, F.R.S.

The authors have employed a special form of extensometer, in conjunction with a Le Chatelier pyrometer, in order to trace the changes in the length of metallic rods during the process of annealing, and have thus obtained continuous curves connecting dilatation and temperature. The rods, which were ¼-inch in square section and 35 inches long, were uniformly and regularly heated in a gas-fired furnace. The chief feature of the apparatus was the use of water-cooled copper tubes for connecting the rod with the extensometer, a plug of non-conducting material being used to prevent any cooling of the end of the rod by the water. By this method the whole of the rod was in the furnace and uniformly heated, while the rest of the system was maintained at a constant temperature. The water-cooled tube attached to one end of the rod was firmly clamped, the other being free to move. On to this tube was screwed a brightly polished brass disc, against which pressed a finely rounded projection attached to the short arm of a bell-crank lever, which, traversing a scale, indicated the expansion of the rod.

The scale was divided into millimetres, each millimetre representing 1/1200-inch expansion, corresponding to a magnification of 48 : 1. The suitability and delicacy of the apparatus were ascertained by testing bars of wrought iron and steel; from the former a regular line was obtained, while the latter gave a curve showing a marked change of volume at the critical point (about 690° C.), thus agreeing with Le Chatelier's results obtained by an entirely different method. Hard-drawn copper bars gave a perfectly regular line, similar to that obtained with wrought iron; annealed copper also gave a straight line. Experiments on rods of brass of different composition, on gun-metal, and on phosphor bronze gave similar results.

It thus appears that the change from the hard, elastic condition of worked copper and copper alloys to that of extremely soft metal is not accompanied by any alteration in length. On the other hand, it is known that allotropic changes in an element, such as occur in pure iron at about 880°, or such chemical constitutional changes as occur in iron-carbon alloys at critical temperatures, are accompanied by marked alterations in volume, and the authors therefore conclude that the changes brought about by mechanical work, or by annealing of worked metals, produce only internal re-arrangement of the metallic molecules, but are of a different order from the chemical and physical changes, such as are correctly regarded as allotropic.

"Experiments on a New Kathode Dark Space in Helium and Hydrogen." By F. W. **Aston**. Communicated by Prof. J. H. Poynting, F.R.S.

This paper is a description of a new dark space, close up to the kathode and inside the Crookes dark space, discovered by the author while investigating the length of the latter phenomenon in helium, and later found to be exhibited in a less marked degree in hydrogen. The length of the new dark space, which under measurable conditions varies from 0·2 mm. to 1·0 mm., is almost unaffected by the pressure of the gas, but varies roughly with the inverse square root of the current density.

Careful observations show that *the fall of potential across the new dark space is constant* for the same gas under all observed conditions, and is in helium 30 volts, in hydrogen 15 volts. The phenomenon may be accounted for by the supposition that the energy required to ionise a molecule of helium is a definite quantity, and that an electron liberated from the surface of the kathode virtually at rest must fall freely through a definite potential in order to acquire that energy, so that the new dark space may be regarded as *the distance through which the electrons fall in order to attain sufficient energy to ionise the gas by collision with its molecules.*

The intense blackness of the new dark space in pure helium bears out this theory, by which also the following effect was predicted:—Since the behaviour of electrons liberated from molecules of the gas by collisions should be the same as that of those derived from the kathode, if the ionisation just beyond a potential distance from the kathode of 30 volts is sufficiently concentrated there will be a further maximum of ionisation—and therefore of light—just beyond a potential distance of 60 volts, another beyond 90 volts, and so on, each getting less definite than the previous one, so that the light in the Crookes dark space should be striated in appearance. By suitable adjustment of conditions, several successive striations can be seen and photographed in helium. Combining the potential differences obtained from the length of the new dark space with the accepted values of e and m for the electron, the following values of the energy required to ionise and the velocity of the ionising electron are obtained:—

Hydrogen	...	$1{\cdot}7\times10^{-11}$ ergs	$2{\cdot}25\times10^{8}$ cm. per sec.
Helium...	...	$3{\cdot}4\times10^{-11}$,,	$3{\cdot}2\times10^{8}$,,

Not the slightest indication of the phenomenon has yet been observed in any other gas.

Received July 5.—"The Dispersion of Double Refraction in Relation to Crystal Structure." By Dr. T. H. **Havelock**. Communicated by Prof. J. Larmor, Sec.R.S.

In this paper the object is to consider to what extent it is possible to regard double refraction, whether produced artificially or occurring in natural crystals, as due simply to an æolotropic distribution of similar particles. The ordinary theory of double refraction amounts to considering the medium as a collection of crystal molecules in cubical order, all the varieties of dispersion being postulated of the single particle; and similarly in artificial double refraction, the æolotropy is assumed to originate wholly in the individual molecule, and to be effected through the quasi-elastic force under which the polarisation electrons are supposed to vibrate. On the other hand, a theory which confines the effect to a re-arrangement of the molecules in space will express the result by a modification of the effective electric force operative at each particle. From this point of view the author develops a theory of the optical properties of a homogeneous assemblage of isotropic particles. If the medium behaves like a uniaxal crystal, it is found that the double refraction, equal to the difference between the two principal indices, is proportional to $(n_0^2-1)^2/n_0$, where n_0 is a mean value measuring the refractive index of a medium composed of the same particles in the same density, but arranged in simple cubical order.

This gives a law of dispersion of the double refraction, provided the dispersion of the mean index n_0 is known. The formula is applied first to the double refraction produced artificially in simple isotropic media. Experimental data are available for the dispersion of the double refraction produced in carbon disulphide by an electric field, and these results are found to agree well with the formula given above.

In the case of natural crystals, where the effect is larger, the theory indicates that the quantity

$$(n_1^2-1)^{-1}-(n_2^2-1)^{-1}$$

should be independent of the wave-length, n_1 and n_2 being the ordinary and extraordinary indices of the crystal. This relation is found to hold very well for quartz over a wide range, and gives in this case the equation

$$n_2^2-n_1^2=0{\cdot}01441(n_1^2-1)(n_2^2-1).$$

It follows, further, that the double refraction decreases in absolute value with the mean index n_0, that is, it decreases in general with increasing wave-length. This is the rule of dispersion in most actual crystals, but there

are various exceptional cases of anomalous dispersion, and to cover these a modified theory of uniaxal crystals is given in the following terms. The molecules (or crystal units) of the medium are not necessarily to be supposed ellipsoidal in shape, but are optically æolotropic, so that the subsidiary equations connecting the polarisation of a particle with the effective electric force are æolotropic, with an axis of symmetry; the particles are supposed to be arranged in a homogeneous assemblage, such that the effective cavity may be taken as a spheroid of small ellipticity with its axis of symmetry coincident in direction with that of the crystal unit. Hence an explanation is given of the anomalous dispersion of the double refraction in regions free from absorption, that is, when a medium composed of the same crystal units arranged in regular cubical order would give regular dispersion. The theory is considered finally in its general application to dispersion in biaxal crystals.

The author has attempted to connect the varieties of dispersion of double refraction with the structure of the crystal under the following assumptions. The crystal unit contains vibrating electrons, so that their combined effect is expressed by three principal equations connecting the polarisation of the unit with the effective electric field; if, then, these units are arranged in regular cubical order, we have a medium with principal refractive indices along three fixed directions in space, and in this case it is assumed that there is regular decrease of the double refraction with increasing wave-length in regions away from absorption bands; but considering in general any other homogeneous assemblage, the effect is expressed by a change in the effective electric field acting on the crystal unit; this effect is estimated by supposing, as a sufficient approximation, that the effective cavity is slightly ellipsoidal instead of being spherical. Thus differences of packing of the crystal molecules are represented optically by variations in the ratios of the axes of the effective cavity and in their directions in space compared with the polarisation axes of the individual unit. Combining these assumptions, it is shown that they are sufficient for a descriptive theory covering the varieties of dispersion of double refraction found in natural crystals.

PARIS.

Academy of Sciences, October 7.—M. Henri Becquerel in the chair.—The spectrum of the Daniel comet, 1907*d*: Jean **Bosler.** The spectrum of the nucleus of the comet was photographed on the nights of August 8 to 9, 18 to 19, and 19 to 20, with exposures of forty minutes, one hour, and one hour and ten minutes. Details are given of the lines observed, which appear to indicate the presence of hydrocarbons and cyanogen. There are also some lines of which the origin is uncertain.—Trigonometric series: Marcel **Riesz.**—The execution of a geodesic chain of precision in the Savoy Alps: Paul **Helbronner.** Particulars are given of the immediate objects of the survey, together with a list of the thirty-three stations, mostly mountain peaks, proposed to be included in the survey. Of these, twenty-six were completed between June 12 and September 28.—Spectroscopes with mirrors: Maurice **Hamy.** The substitution of mirrors for objectives is often used in spectroscopes. The present note gives a study of the theory of the best position to give the face of the last prism or grating to obtain a field of images as flat and as extended as possible.—The thermoelectricity of nickel; the influence of foreign metals: H. **Pécheux.** Three specimens of nickel were studied, the chemical analysis of each being determined. Couples were formed of each of these with pure copper, and the thermoelectromotive forces studied for a temperature range of 640° C. The curves of electromotive force of the three couples were not parallel, but the results are comparable, differing only by about 0·25 per cent. on the average. The simultaneous existence of copper and cobalt in a specimen of nickel produces the most marked deviations of E.M.F.—Phenyl migrations in the aromatic iodohydrins by the elimination of HI from the same atom of carbon: M. **Tiffeneau.** The theory developed in previous papers regarding the migration of the phenyl group in compounds of the type

$$(Ar)R—C(OH)—CHI—R'$$

has been extended and confirmed by a study of the corresponding ether oxides.—The phases of development of the Epicaridæ; experimental verification of the nature of the Microniscidæ: Maurice **Caullery.**—The presence of Tyroglyphinæ in the long bones of the wings of birds: E. L. **Trouessart.**—The existence of statoblasts in the scyphistome: Edgard **Hérouard.**—The necessity of cultures in the study of the gonococcus: A. **Guépin.** The absence of the gonococcus, and of any other pathogenic microbe, can only be admitted as proved after negative results have been obtained from systematic cultures.—Some new fossil plants from the travertine of Sézanne: René **Viguier.**

DIARY OF SOCIETIES.

FRIDAY, OCTOBER 18.

INSTITUTION OF MECHANICAL ENGINEERS, at 8.—The Indicated Power and Mechanical Efficiency of the Gas Engine: Prof. B. Hopkinson.

THURSDAY, OCTOBER 24.

CHEMICAL SOCIETY, at 8.30.—The Constitution of Phenol- and Quinol-phthalein Salts: a Contribution to the Quinonoid Theory of Colour: A. G. Green and P. E. King.—Poly-ketides: J. N. Collie.—Production of Orcinol Compounds by the Action of Heat on the Sodium Salt of Ethylacetoacetate: J. N. Collie and E. R. Chrystall.—A Simple Gas Generator for Analytical Operations: J. M. Sanders.—Some Double Ferrocyanides of Calcium, Potassium and Ammonium: J. Campbell Brown.—Halogen Determination in Organic Substances: J. Moir.—Racemisation by Alkali as applied to the Resolution of *r*-Mandelic Acid into its Optically Active Isomerides: A. McKenzie and H. A. Müller.—The Optical Activity of Cyclic Ammonium Compounds: F. Buckney and H. O. Jones.—Keten. A New Anhydride of Acetic Acid: N. T. M. Wilsmore.—The Action of Phosphorus Pentachloride on Hydroxy-trimethyl Succinic Ester. 1:2-Dimethyl Trimethylene 1:2-Dicarboxylic Acid: H. Henstock and B. E. Woolley.

CONTENTS.